Oyster Shell as Roughage Replacement in Cattle Diets

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Mechanization, specialization, increased labor costs, and more efficient production methods have forced modern cattle feedlots to locate a roughage or roughage substitute which is more adaptable to mechanized handling and feeding than hay or cottonseed hulls. Roughage or roughage substitutes must be inexpensive, readily available, and adaptable to mechanized handling and feeding. Oyster shell, a bulky, inexpensive, apparently harmless feed ingredient seemed to offer promise in fulfilling these requirements.

Experimental Procedure

Two digestion trials were employed by randomly allotting three mature, fistulated Hereford steers and three mature, fistulated Angus steers in a 3 x 3 Latin square design. Each animal was offered, *ad libitum,* identical diets with the exceptions that diet I had 10 per cent Coastal Bermudagrass (*Cynodon dactylon*) hay, diet II had 10 per cent cottonseed hulls, and diet III had 2.5 per cent oyster shell. No other source of roughage was available to the animals.

A 93-day feeding trial was divided into three 31-day periods, each animal rotating to a different diet after each period. Periods were divided into the following five phases:

1. A 7-day adjustment phase to allow the animal and rumen flora to adjust to the new feed and to clean the digestive tract of previous feed.
2. A 14-day voluntary feed intake phase to determine the relative quantity of each diet that the animals would consume.
3. A 5-day adjustment phase to allow the animals to become adjusted to the fecal collection bag apparatus.
4. A 5-day total fecal collection and digestibility phase.
5. A 1-day rumen sampling phase at the end of the total collection phase. Rumen fluid samples were withdrawn just prior to feeding and at 1, 3, and 5 hours after feeding.

The steers were housed in an open, pole-type barn at the Purebred Experimental Beef Cattle Unit and were confined to stanchion type stalls. Stalls were equipped with rubber matting on the floors, individual automatic watering cups, and one 1 m x 1 m x 1.5

m feeding box which kept food wastage at a minimum. Each stall was cleaned daily. The steers were taken out of confinement only for periodic weighings (prior to and directly following the 14-day voluntary feed intake phase) and for the first four days of the 7-day adjustment period while changing rations.

The animals were fed twice daily, at 7:00 AM and at 5:00 PM. At feeding time, the feed boxes were emptied and the orts weighed and subtracted from the quantity fed in order to accurately calculate voluntary feed intake. The steers consumed most of their feed within two hours after feeding, although food was kept before them at all times.

A total collection digestion trial was conducted in order to accurately determine the apparent digestibility of components of the different diets. Feces were collected twice daily for five days in each period. The method of feces collection was a revised form of the method described by Noller, et al. (1959). Polyethylene bags were made from 6 mil polyethylene, were 2.5 m long and approximately the width of the respective steers. The bags were attached to the animals by means of canvas webbing cemented to their hide with contact cement. The unattached end was tied off and rested on the floor.

A 10 per cent representative sample of fresh feces was taken daily, dried in a forced air oven for 72 hours at 65 C, and stored in polyethylene bags to equilibrate to room temperature. At the end of each period, the pooled samples of dried feces were weighed, ground finely in a Wiley Laboratory Mill Standard Model No. 3, and mixed. A 40 gm aliquot was stored in 130 ml glass bottles for analysis.

Representative samples of the feed and orts were collected daily during the 5-day digestion trial and pooled. A 50 gm aliquot of the feed and orts was finely ground in a Wiley Mill and stored in glass bottles for analysis.

Crude protein, ether extract, crude fiber, nitrogen-free extract, and ash content were determined for each feed, feces, and orts sample. The methods used are described by the A.O.A.C. (1960). Total digestible nutrients were calculated using the method described by Maynard and Loosli (1962).

Digestibility coefficients were calculated for the components of each ration during each period.

Rumen fluid samples were taken immediately before feeding and 1, 3, and 5 hours after feeding. The samples were obtained by using a 1 1/2" plastic pipe with a removable plug on one end. The pipe was inserted through the fistula and immersed in the rumen fluid. The plug was then removed, allowing the pipe to fill with fluid. Samples of rumen fluid were taken by replacing the plug and withdrawing the pipe.

Rumen fluid samples for pH and volatile fatty acid determinations were transferred directly from the samples to glass beakers for pH analysis. After measuring pH, 50 ml of strained rumen fluid was mixed with 0.5 ml of mercuric chloride to stop bacterial action, then the preserved sample was frozen in glass bottles for volatile fatty acid analyses at a later time.

Volatile fatty acid concentrations were measured by gas-liquid chromatography using a 1/4" x 5' stainless steel column packed with 10 per cent diethylene glycol adipate and 2 per cent phosphoric acid on Chromosorb W. Samples were centrifuged at 2200 rpm for 5 minutes and acidified by adding 1 ml of 20 per cent phosphoric acid to 5 ml of supernatant and centrifuged again. The acidified samples were injected without further treatment. The chromatograph was fitted with a hydrogen flame ionization detector and peaks were integrated with a Disc integrator. Total volatile fatty acid concentrations were calculated by adding the molar concentrations of acetate, propionate, butyrate, iso-valerate, and valerate. Molar per cents for individual acids were determined by dividing the individual fatty acid concentration by the total volatile fatty acid concentration.

RESULTS

All steers readily consumed the Bermudagrass hay and cottonseed hull diets. Steers, when switched to the oyster shell diet, consumed feed less readily; consequently their voluntary feed intake was reduced. Average voluntary feed intakes for steers offered the different diets are as follows: Bermudagrass hay, 12.1 kg/day; cottonseed hulls, 12.7 kg/day; and oyster shell, 10.16 kg/day. These data agree with previously reported data (Woods, 1966a, 1966b; Woods et al., 1967, and Perry et al., 1967).

Steer no. 1, when fed the oyster shell diet, went entirely off feed for four days and was removed from the experiment on February 24, at 10:30 AM. This digestive disorder was judged to be caused by the diet. Steer no. 1 consumed five pounds of the cottonseed hull diet within 1/2 hour after removal from the experiment. At 5:00 PM, the steer was offered 10 pounds of the cottonseed hull diet and 12 pounds of long stem Coastal Bermudagrass hay. All of the feed was consumed by 7:00 the following morning. This marked preference of steers for a natural roughage source instead of an oyster shell replacement for roughage had been reported previously by Woods (1966) and Woods et al. (1967).

When compared to the Bermudagrass hay or cottonseed hull diets, reduced rates of gain were obtained for steers fed the oyster shell diet. Average weight changes were: Bermudagrass hay, 1.92 kg/day; cottonseed hulls, 0.94 kg/day; and oyster shell, 0.77 kg/day. These results agree with previously published data (Woods, 1966; Woods et al., 1967; Perry et al., 1967; Haskins et al., 1967; and McElroy, 1967).

Apparent digestibility coefficients were calculated for the components of each diet. Average proximate constituents of the diets are presented in Table 1. Average digestion coefficients are shown in Table 2.

TABLE 1

Average proximate constituents of the diets, moisture-free basis

	Bermudagrass hay (%)	Cottonseed hulls (%)	Oyster shell (%)
Moisture	9.0	8.4	9.0
Crude protein	10.7	10.5	10.4
Crude fiber	8.9	7.7	4.9
Ether extract	2.9	3.6	3.4
Nitrogen-free extract	73.4	73.6	74.1
Ash	4.1	4.6	7.2
Calcium to phosphorus ratio	3.06:1	2.79:1	3.33:1

TABLE 2

Average apparent digestibility coefficients of components of the different diets

Nutrient	Ration: Bermuda grass hay	Ration: Cottonseed hulls	Ration: Oyster shell
Crude protein	62.88 ± 4.82	56.52 ± 5.75	63.58 ± 3.05
Crude fiber	54.77 ± 2.66	45.07 ± 4.35	66.18 ± 3.98
Ether extract	61.30 ± 1.84	64.11 ± 2.57	67.25 ± 0.94
NFE[1]	64.90 ± 1.87	65.57 ± 2.36	67.97 ± 2.84

[1]NFE, nitrogen-free extract.

Respective values for crude protein content in the Bermudagrass hay, cottonseed hull, and oyster shell diets were 10.7 per cent, 10.5 per cent, and 10.4 per cent. Apparent digestibility coefficients for crude protein in the three diets were: Bermudagrass hay, 62.88 percent; cottonseed hulls, 56.52 per cent; and oyster shell, 63.58 per cent. An explanation for the higher digestibility of crude protein in the oyster shell diet may be based on the previously reported low digestibility of crude protein in Bermudagrass hay (Alexander et al., 1963) and cottonseed hulls (Hale et al., 1967).

Respective values for crude fiber content of Bermudagrass hay, cottonseed hull, and oyster shell diets were 8.9 per cent, 7.7 per cent, and 4.9 per cent. The oyster shell diet was lowest in crude fiber because the oyster shell replaced materials high in crude fiber as reported by Alexander (1961) and Hale et al. (1967). Apparent digestibility coefficients for crude fiber in the three diets were: Bermudagrass hay, 54.77 per cent; cottonseed hulls, 45.07 per cent; and oyster shell, 66.18 per cent. The higher digestibility of crude fiber in the oyster shell diet is due to the removal of previously reported low digestible crude fiber in Bermudagrass hay (Alexander et al., 1963) and cottonseed hulls (Hale et al., 1967).

Values for ether extract content of the Bermudagrass hay, cottonseed hull, and oyster shell diets were 2.9 per cent, 3.6 per cent, and 3.4 per cent respectively. Apparent digestion coefficients of ether extract for the three diets were: Bermudagrass hay, 61.30 per cent; cottonseed hulls, 64.11 per cent; and oyster shell, 67.55 per cent. Differences in apparent ether extract digestibility may be due to different ether extract digestion coefficients of Bermudagrass hay (Alexander, 1963), cottonseed hulls (Hale et al., 1967), and concentrates (Morrison, 1956).

Respective values for nitrogen-free extract (NFE) content in the Bermudagrass hay, cottonseed hull, and oyster shell diets were 73.4 per cent; 73.6 per cent; and 74.1 per cent. Apparent digestibility coefficients for NFE in the three diets were: Bermudagrass hay, 64.90 per cent; cottonseed hulls, 65.57 per cent; and oyster shell, 67.97 per cent. The higher NFE digestibility coefficient of the oyster shell diet agrees with previously reported low NFE digestibilities of Bermudagrass hay (Alexander, 1963) and cottonseed hulls (Hale et al., 1967).

Oyster shell fed as 2.5 per cent of the diet, replacing 10 per cent Bermudagrass hay or 10 per cent cottonseed hulls, did not significantly increase total digestible nutrients (TDN) of the diet. Although all proximate component digestibilities were higher in the oyster shell diets, the TDN was not different due to a higher ash content of the oyster shell diet (Table 1). Respective values for TDN content in the Bermudagrass hay, cottonseed hull, and oyster shell diets were 63.0 per cent, 62.6 per cent, and 64.2 per cent.

Presence of oyster shell in the diet of fattening beef steers decreased voluntary feed intake and decreased rates of gain. Feedlot performance is largely determined by voluntary feed intake and to a lesser extent by digestible energy; therefore, the performance of steers fed an oyster shell diet would be expected to be lower because the presence of oyster shell lowered voluntary feed intake and did not increase TDN of the diet.

Average rumen fluid pH values were lowest for the steers fed the oyster shell diet. Oltjen and Davis (1965) reported that steers fed all-concentrate rations might have rumen fluid pH values as low as 5.4. Their explanation for the low pH was a lack of rumination by steers fed oyster shell or all-concentrate diets. An absence of rumination decreases the amount of saliva produced. A decrease in saliva production reduces the buffering capacity of the rumen fluid resulting in a lower pH.

The average total volatile fatty acid concentrations (TVFA) in rumens of steers fed the Bermudagrass hay, cottonseed hull, and oyster shell diets were 126 mM/1, 136 mM/1 and 130 mM/1, respectively.

Average concentrations of individual volatile fatty acids present in the rumen at different times after feeding are presented in Table 3. C_2/C_3 ratios were lower in the rumen fluid of steers fed the oyster shell diet than they were in the Bermudagrass hay or cottonseed hull diets. This lower C_2/C_3 ratio was expected because of the roughage free diet (Oltjen and Davis, 1965 and Thompson et al., 1965).

General Discussion

Replacement of cottonseed hulls or Bermudagrass hay by oyster shell had no significant effect on the digestion of the proximate

TABLE 3

Molar proportions of individual volatile fatty acids in the rumen at different times after feeding

Ration	Hours after feeding	Volatile fatty acids, mM/1					
		C_2	C_3	C_4	iC_5	C_5	C_2/C_3
Bermudagrass hay	0	68.09	22.38	13.68	2.98	2.21	3.29:1
	1	85.75	24.00	18.25	4.60	2.45	3.63:1
	3	83.23	30.58	22.48	3.68	4.13	2.75:1
	5	77.98	29.53	22.55	3.80	4.38	2.70:1
Cottonseed hulls	0	76.48	42.30	13.80	1.86	4.00	1.90:1
	1	93.48	48.88	24.88	1.83	7.25	2.00:1
	3	80.23	44.28	20.58	1.25	5.63	2.00:1
	5	69.68	29.83	24.18	1.60	2.03	2.70:1
Oyster shell	0	52.87	29.77	7.23	1.53	2.87	1.83:1
	1	65.48	43.80	21.88	1.55	5.60	1.48:1
	3	84.30	60.48	30.80	1.93	5.00	1.48:1
	5	65.38	32.88	28.20	1.90	4.25	2.85:1

components of the diet or on the total digestible nutrients of the diet. Digestion coefficients for components of the oyster shell diet were higher than in the other two diets. This might be due to two factors. First, the steers fed the oyster shell diet consumed less feed per day; therefore, the feed would be expected to be utilized more efficiently. Secondly, the oyster shell comprised only 2.5 per cent of the diet permitting the addition of 7.5 per cent of highly digestible components as compared with diets containing 10 per cent cottonseed hulls or Bermudagrass hay, both of which have relatively low digestibility coefficients.

Differences in rumen fluid total volatile fatty acids or molar proportions of individual volatile fatty acids were not significant. Rumen fluid pH changes, although lower in the oyster shell-fed animals, were not significantly different when compared with the diets.

Total voluntary feed intake by steers was 26 per cent lower with the oyster shell diets than with the Bermudagrass hay or cottonseed hull diets (10.2 kg/day, 12.1 kg/day, and 12.7 kg/day, respectively). Body weight gains of steers were lowest for the oyster shell diet (0.77 kg/day) when compared with the cottonseed hull diet (0.94 kg/day) and the Bermudagrass hay diet (1.92 kg/day).

In a preliminary investigation, the author compared oyster shell and coquina shell, a small uncrushed shell with smooth edges and a lacquer-like finish. Both types of shell, when mixed into all-concentrate diets at a 2.5 per cent level, were readily consumed by fistulated steers. Stratification of rumen contents and condition of rumen mucosa were observed by removing the rumen contents with an industrial vacuum cleaner. Both shell diets produced a similar rumen stratification characterized by a foamy top layer about six inches deep, a viscous middle layer containing most of the feed particles, and a well mixed corn and shell layer of dense particles on the bottom. Shell was observed only in the lower layer of contents in the ventral part of the ruminoreticulum.

Rumen papillae of steers fed the oyster shell diet showed more lacerations of the epithelium than rumen papillae of steers fed the coquina shell diet. These lacerations might be explained by visual observations of the shells. The coquina shell was smooth with well rounded edges while the oyster shell was rough with very sharp and jagged edges.

The solubility of coquina shell in the gastrointestinal tract is believed to be lower than for oyster shell. This belief was supported by observations of the consistency of feces and the solubility of the shells in acid solutions. Approximately 1/3 of the coquina shell in the diet was recovered in the feces while no oyster shell was recovered. Solubility tests showed that oyster shell was more soluble than coquina shell. When both types of shell were placed in simulated abomasal fluid solutions (pH 2.5) that were constantly stirred and maintained at 39 C, the oyster shell dissolved within three hours while the coquina shell had not dissolved in seven hours but did dissolve within 24 hours. At a pH 5.4, which simulated ruminal conditions, the coquina shell did not dissolve while oyster shell dissolved within 48 hours. These results indicate that the feeding of a smooth, less soluble shell as a roughage substitute may be beneficial.

SUMMARY

Oyster shell, as 2.5 per cent of an all-concentrate diet, was compared with similar diets containing 10 per cent Bermudagrass hay or 10 per cent cottonseed hulls. Rumen volatile fatty acid concentration, rumen fluid pH changes, ration component digestion, and voluntary feed intake were determined in two experiments with six, mature, fistulated steers.

Voluntary feed intake by steers fed the diet containing oyster shell was 26 per cent lower than with either of the other diets. Digestibility of the proximate components of the oyster shell ration was higher than in either the Bermudagrass hay or cottonseed hull diets but total digestible nutrient (TDN) values were not different among the three diets due to a high ash content of the oyster shell diet.

Acidity of the rumen fluid was highest in steers fed the oyster shell diet. Rumen fluid volatile fatty acid concentrations and molar proportions of individual volatile fatty acids were not different among the steers.

Statistical analysis did not reveal significant differences.

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